扬声器制造业中驱动和悬吊系统非线性的快速测量

Fast Measurement of Motor and Suspension Nonlinearities in Loudspeaker Manufacturing

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KLIPPEL

在线测试的目标

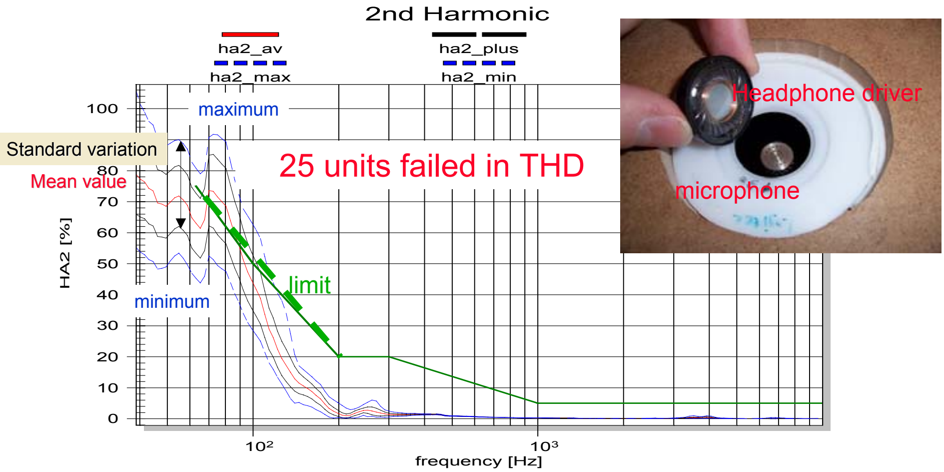
Objectives in end-line-testing:

1. 基本目标:将有缺陷的单元从交货的产品中分离出来.
   Basic Goal: Separate defect units from delivered goods
   → 使用限制文件简单进行PASS/FAIL判定 simple PASS/FAIL decision using limits

2. 最终目标 :避免制造出不良的产品
   Ultimate Goal: Avoid manufacturing of defect units
   → 使用诊断来获取有意义的特性反馈来控制生产过程 use diagnostics to get meaningful characteristics used as feedback in controlling the production process

二次諧波失真

2nd-order Harmonic Distortion
batch A (30 Duts)



如何來減小不良率?

How to reduce the rejection rate ?

步驟Steps:

1. 物理原因是什麼？ What is the physical cause ?
2. 如何能快速地檢測出物理原因？ How can the cause quickly be detected ?
3. 如何使用這些信息來進行過程控制？ How to use this information for process control ?

目标: 减小不良率 Target: Reduce Rate of Rejection
解决方案: 在线诊断 Solution: On-line Diagnostics

不良单元
Defective Unit

Fault Analysis

系统本身
Systematic

偶然性
Accidental

物理产生
Physical Cause
Glue problem
Bad spider
Voice coil offset
Loose particle

调节过程
Adjust Process

维修单元
Repair unit

重新使用单元
Recycle unit

從諧波成分中獲取訊息
Exploiting Information from Components

Harmonic Distortion

2次諧波失真
2nd-order harmonic distortion
→ 非線性曲線不對稱
Asymmetry of nonlinear curve shape

3次諧波失真
3rd-order harmonic distortion
→ 非線性曲線對稱度
Symmetry of nonlinear curve shape

高次諧波失真
higher-order harmonic distortion
→ 限制，雜音，線撞擊
Limiting, rub&buzz
Wire beat

存在問題
Open Questions:

非線性的種類
What kind of nonlinearity ?

自身缺陷還是裝配問題？
A defective part or an assembling problem ?

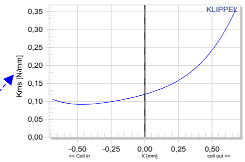
如何修理問題
How to fix the problem ?

基於非線性參數的診斷

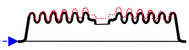
Diagnostics based on Nonlinear Parameters

大信號識別
Large Signal Identification (LSI)

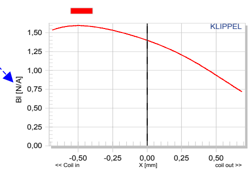
But the measurement time > 10 minutes



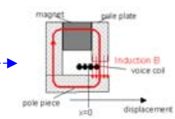
勁度係數曲線
Stiffness
Kms(x)-curve



悬吊结构
Suspension Geometry



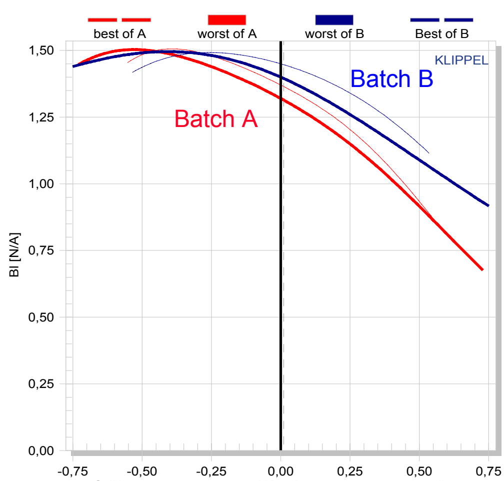
耦合係數曲線
Force Factor
Bl(x)-curve



线圈偏移
Coil Offset

耦合系数曲线

Force Factor Curve Bl(x)

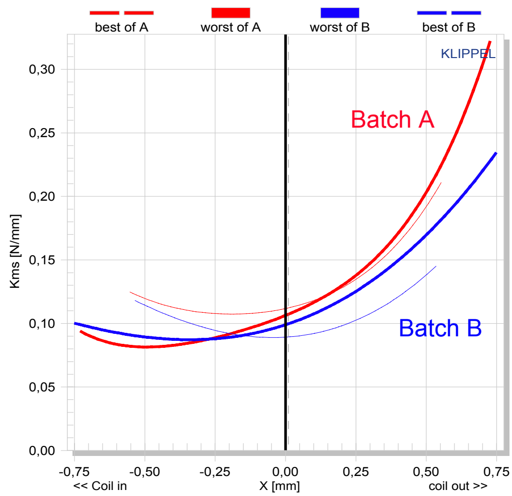


大信号识别技术测量的曲线
Curve measured by using Large signal Identification (LSI)

测量时间 ：10min
Measurement time: 10 min

劲度系数曲线

Stiffness Curve Kms(x)



大信号识别技术测量的曲线

Curve measured by using Large signal Identification (LSI)

测量时间：10min

Measurement time: 10 min

非線性曲線對在線測試有用嗎？

Are nonlinear curves good for end-of-line testing ?

Good point:

- 曲線提供所有相關的訊息 Curves provide all relevant information

Bad points:

- 全部識別需要更多的時間 Full identification requires more time
- 複雜的狀態導致解釋困難 Complexity makes interpretation difficult
- 曲線表徵多種多樣的物理原因 Curves reveals multiple physical causes
- 不可以運用Cpk, Ppk Cpk and Ppk can not be applied

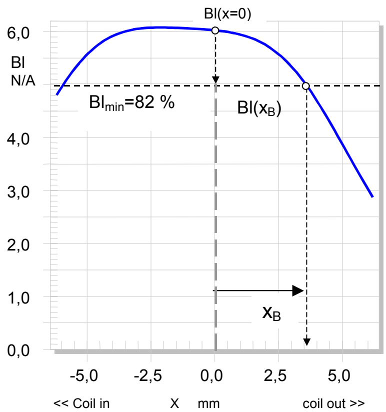
→ 單值數據的規格參數顯示更適合於QC

single-value characteristics are preferable for QC

耦合係數限制的偏移X_B

Force Factor Limited Displacement x_B defined according IEC standard 62458

根據IEC 62458 標準規定



Criterium:

最大峰值偏移Xb產生10% 的互調失真

Maximal Peak Displacement x_B generating 10 % intermodulation distortion

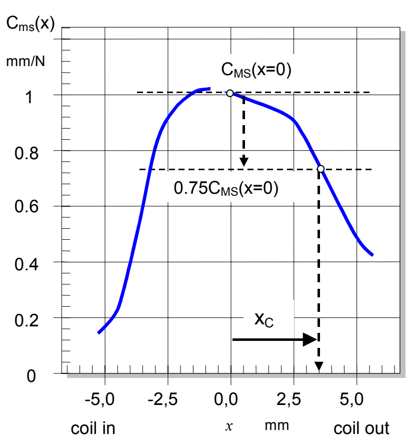
Steps:

1. 在大訊號模式下激勵換能器Operate transducer in large signal domain
2. 在耦合係數下降到靜態位置 Bl(x=0) 的82%的地方讀取偏移數值X_B
   Read displacement X_B where force factor $Bl(x_{ac})$ decreases to 82 % of the value Bl(x=0) at rest position

順性係數限制的偏移x_C

Compliance Limited Displacement x_C defined according IEC standard 62458

根據IEC 62458標準規定



Criterium:

最大的峰值偏移產生10%的諧波失真

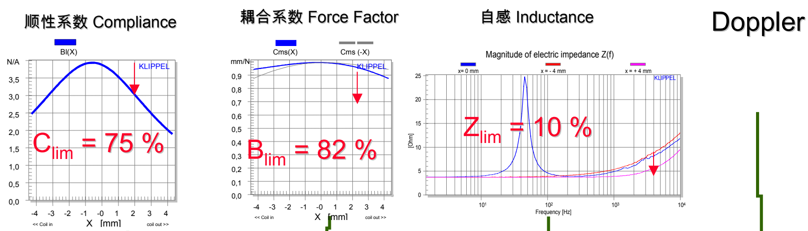
Maximal Peak Displacement x_C generating 10 % harmonic distortion

Steps:

1. 在大訊號模式下激勵換能器
   Operate transducer in large signal domain
2. 在順性係數下降到靜態位置的75%的地方讀取偏移值Xc
   Read displacement X_C where compliance value $C_{ms}(x_{ac})$ decreases to 75 % of the value $C_{ms}(x=0)$ at rest position

Xmax和其他位移限制

Xmax and other Displacement Limits



X_c	X_{Bl}	X_L	X_D
X limited by Cms(x)	X limited by Bl(x)	X limited by Le(x)	X limited by Doppler
10 % THD	10 % IMD	10 % IMD	10 % IMD

minimum

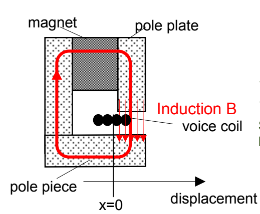
X_{max}

產生不超過10%的THD或10%的IMD

Generating not more than 10 % THD or 10 % IMD

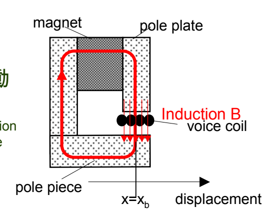
校正音圈的靜態位置

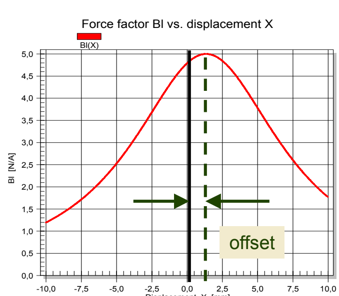
Adjusting Coil‘s Rest Position

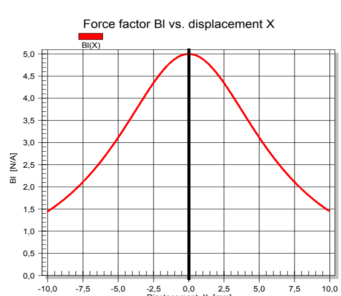


根據Bl曲線來移動音圈的靜態位置

Shifting the coil‘s rest position by the offset of the Bl curve



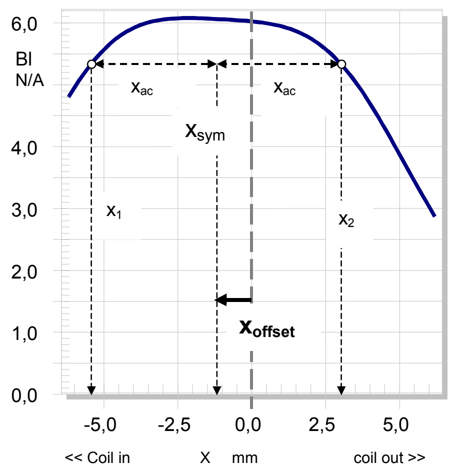




音圈偏移X_{offset}

Voice Coil Offset x_{offset} defined according IEC standard 62458

根据IEC 62458标准定义



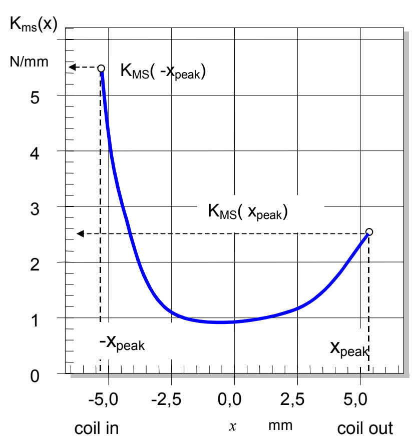
步骤 Steps:

1. 在大信号模式下激励换能器
   Operate transducer in large signal domain
2. 在最大峰值位移xac处读取对称点Xsym
   Read symmetry point X_{sym} at maximal peak displacement x_{ac}
3. $X_{offset}=x_{sym}$ if $X_{ac} > X_{Bl}$

劲度不对称度 A_k

Stiffness Asymmetry A_K defined according IEC standard 62458

根据IEC62458标准定义



步骤 Steps:

1. 在大信号模式下激励换能器
   Operate transducer in large signal domain
2. 在最大峰值偏移处读取劲度值
   Read stiffness values $X_{ms}(X_{peak})$ and $X_{ms}(-X_{peak})$ at maximal peak displacement
3. 根据公式计算劲度不对称度
   Calculate stiffness asymmetry according

$$A_K(x_{peak}) = \frac{2\left(K_{MS}(-x_{peak}) - K_{MS}(x_{peak})\right)}{K_{MS}(-x_{peak}) + K_{MS}(x_{peak})} 100\%,$$

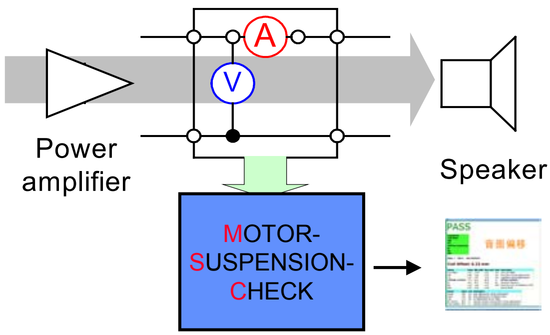
驱动和悬吊系统检查

Motor & Suspension Check (MSC)

用于品质控制的特别的LSI

Special LSI dedicated to Quality Control (e.g. end-of-line testing)

电压和电流 Voltage & current



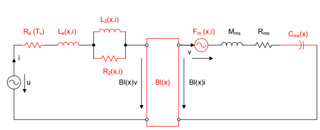
结果 Results:

- 音圈偏移 Voice coil offset
- 悬吊不对称度 Suspension asymmetry
- 测量过程中的峰值位移 peak displacement
- 10%失真时的位移 Displacement (Xmax) producing 10 % distortion
- X=0处的T/S参数 T/S parameters at x=0
- 箱体参数 Box parameters fb,Qb
- x=0处的阻抗 Impedance at x=0

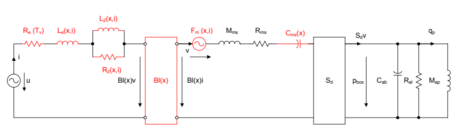
0.2 –2 s 测量时间 0.2-2s measurement time

MSC中使用的模型

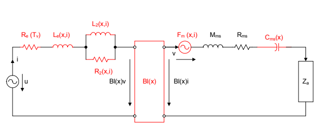
Models used in MSC



- 超低音 Subwoofer
- 低音 Woofer
- 耳机 Headphone
- 小型喇叭 Microspeaker
- 麦克风 Microphone
- 混合器 Shaker



带孔的箱体系统 Vented-box system



$$Z_a(s) = \frac{(s-a_1)(s-a_2)}{(s-b_1)(s-b_2)}$$

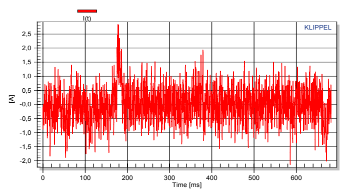
具有复杂的机构或声学负载的系统 System with complex mechanical or acoustical load (panel, horn, transmission line)

MSC中使用的特殊的激励信号

Special Stimulus used in MSC

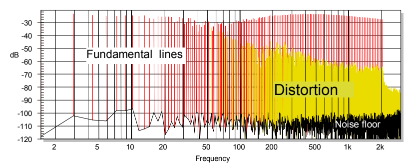
- 需要对换能器设备进行持续的激励
  Persistant excitation of the transducer is required !
- 少量的，综合不同的长度的多音信号是最佳的激励
  Sparse multi-tone complex of length T is the best stimulus
- 需要预激励来达到稳定状态
  Pre-excitation (fraction of T) is required for steady state

测量所得电流的波形
Waveform of the measured current



T= 170 ms ... 2.7 s

测量所得电流的频谱
Spectrum of the measured current



失真是鉴别非线性的基础
Distortion are the basis for the identification of the nonlinearities

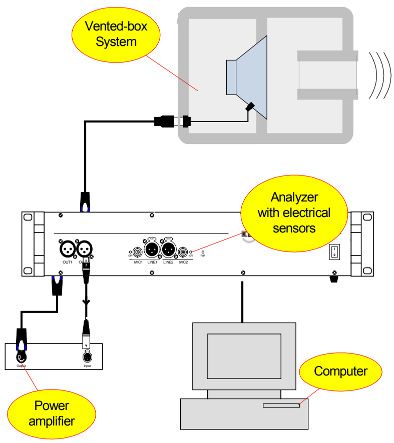
MSC的高速测量

High Measurement Speed of MSC

喇叭类型 Speaker Type	典型的共振频率 Typical resonance frequency	典型的激励长度 Typical stimulus length	最小激励长度 Minimal stimulus length
Subwoofer	30 Hz	2.73 s	**1,3 s**
Woofer	60 Hz	1.3 s	**0.68 s**
Midrange	300 Hz	0.68 s	**0.34 s**
Tweeter	2000 Hz	0.17 s	**0.17 s**
Headphone	100 Hz	0.68 s	**0.34 s**
Microspeaker	500 Hz	0.34 s	**0.17 s**
Exciter (shaker)	100 Hz	0.68 s	**0.34 s**
Closed-box System	60 Hz	1.3 s	**0.68 s**
Vented-box System	50 Hz	1.3 s	**0.68 s**

不需要额外的感应器

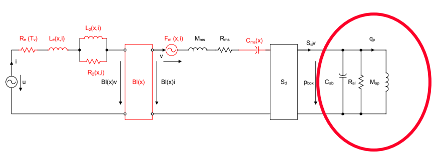
No Additional Sensor Required



- 在连接端仅仅测量电压和电流
  Only voltage and current is monitored at the terminals
- 换能器安装好了也能够检测出驱动和悬边Motor and suspension can be checked when the transducer is mounted in enclosure
- 可以通过长线材测量Measurement via long cables possible
- 对环境噪声的免疫
  Full immunity against ambient noise

测试密闭体

Testing the Enclosure



•传统的测量表征扬声器系统的总体表现 Conventional measurements show total behavior of the loudspeaker system

•MSC将驱动单元的缺陷与密闭体的缺陷区别开来 MSC separates defects in the drive unit from defects of the enclosure (port, sealing, damping)

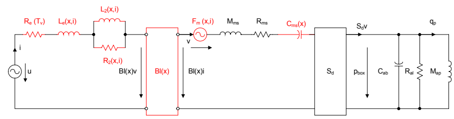
•不必将驱动单元拿到密闭体外面来
No need for taking the drive unit out of the enclosure

•对租赁的客户来讲，是防止由于老化、疲累、气候的影响的检测扬声器系统品质的最佳选择
Perfect for checking the quality of loudspeaker systems in rental companies due to ageing, fatigue, climate influences

单一数值参数总览

Overview on Single-Valued Parameters representing loudspeaker nonlinearities in MSC

MSC中表征扬声器非线性



Parameters at x=0

Thiele-Small Parameters

Electrical Parameters
R_e, L_e

Relative Parameters
$f_s, Q_{ts}, Q_{ms}, Q_{es}, f_b, Q_b$

Mechanical Parameters
$Bl, M_{ms}, R_{ms}, C_{ms}, K_{ms}$

Nonlinear Parameters at $x=x_{peak}$

Stiffness asymmetry A_K

Voice Coil Offset x_{offset}

Xmax for 10 % distortion in IMD or THD

Compliance limited displacement x_C

Force factor limited displacement x_B

MSC的灵敏度

Sensitivity of MSC, Example showing Influence of Gravity on Voice Coil Position

重力对音圈位置的影响的样例

X_{offset} = 0.060 mm	X_{offset} = 0.072 mm	X_{offset} = 0.084 mm

$$\Delta X_{offset} = -12\mu m \qquad \Delta X_{offset} = 12\mu m$$

Prediction using
gravity constant g=9.81 ms^{-2}
Moving mass Mms= 4.94 gram
Compliance Cms(x=0)= 0.4 mm/N
Compliance Cms(x=3mm)= 0.2 mm/N

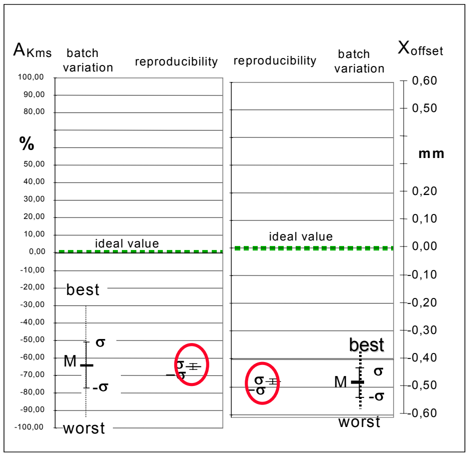
$$\Delta X_{offset} = M_{ms} g C_{ms} \approx 10 \ldots 20\ \mu m$$

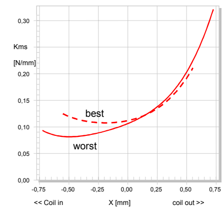
MSC的可重现性

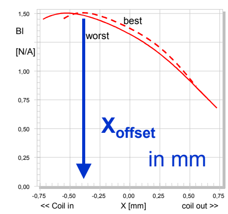
Reproducibility of the MSC

在许多换能器上进行的R&R测量结果

Result of an R&R test performed on various transducers



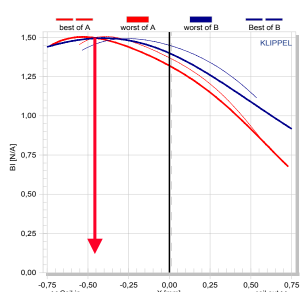




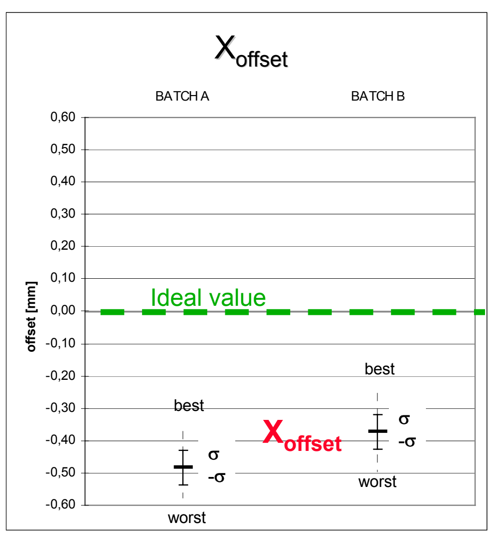
耳机的音圈位移X_{offset}

Voice coil offset X_{offset} of the headphone

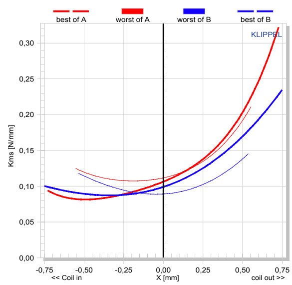
Bl curve measured with R&D

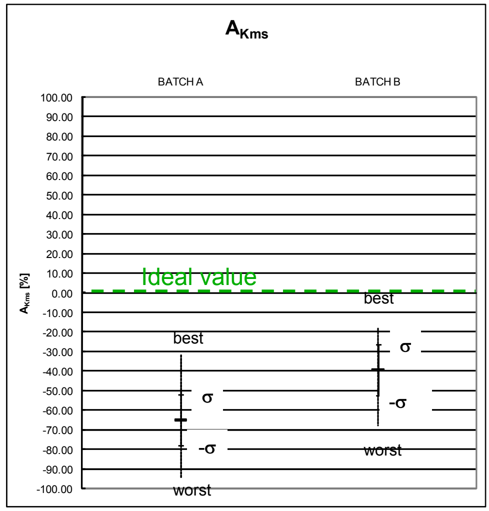


X_{offset} in mm



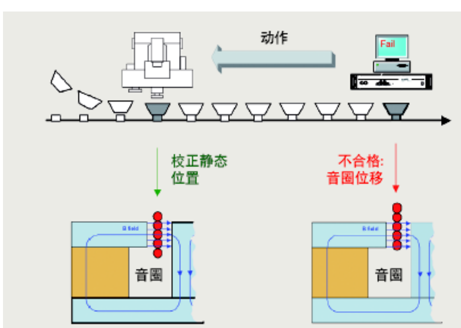
劲度不对称度 Stiffness Asymmetry A_{Kms}





在线诊断

On-Line Diagnostics



如果新的支架系统导致音圈静态位置发生改变时，当第一个产品被KLIPPEL QC 检测到时，音圈的位移量可以马上测量出来；这一信息可以用来校准音圈的静态位置，以及用来补偿悬吊系统改变的部分，有音圈位移问题的扬声器单元就不会输送出来。

KLIPPEL QC系统集成了先进的诊断技术，用于生产线终端测试，简化了测试结果的说明，指示出扬声器缺陷产生的根源。不仅是提供维修的依据，而且还可以发现参数变化的趋势，调节制造过程，及时减少产品不良率，确保产品的高品质和一致性。

→ mimimal rate of rejection 最小化不良率

结论
Conclusion

MSC是一种新的测量技术,提供 MSC is a new kind of measurement providing:

- 全面的驱动和悬吊系统的诊断 full motor and suspension diagnostics
- 单一数值的简单阐述说明 simple interpretation of single-valued parameters
- 指明失真的物理原因 shows physical cause of distortion
- 密闭体的缺陷(泄露,风口,阻尼) defects of the enclosure (leakage, port, damping)
- 对所有的驱动单元适用 applicable to all kinds of drive units
- 小信号和大信号领域 small and large signal domain
- 极短的测量时间 short measurement time (< 1s)
- 强大的, 环境噪声免疫 robust, immune against ambient noise
- 过程控制的基础 basis for process control

->最大限度减小不良率 → minimal rate of rejection